Predicting Emissions from Oil and Gas Operations in the Uinta Basin

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Outline

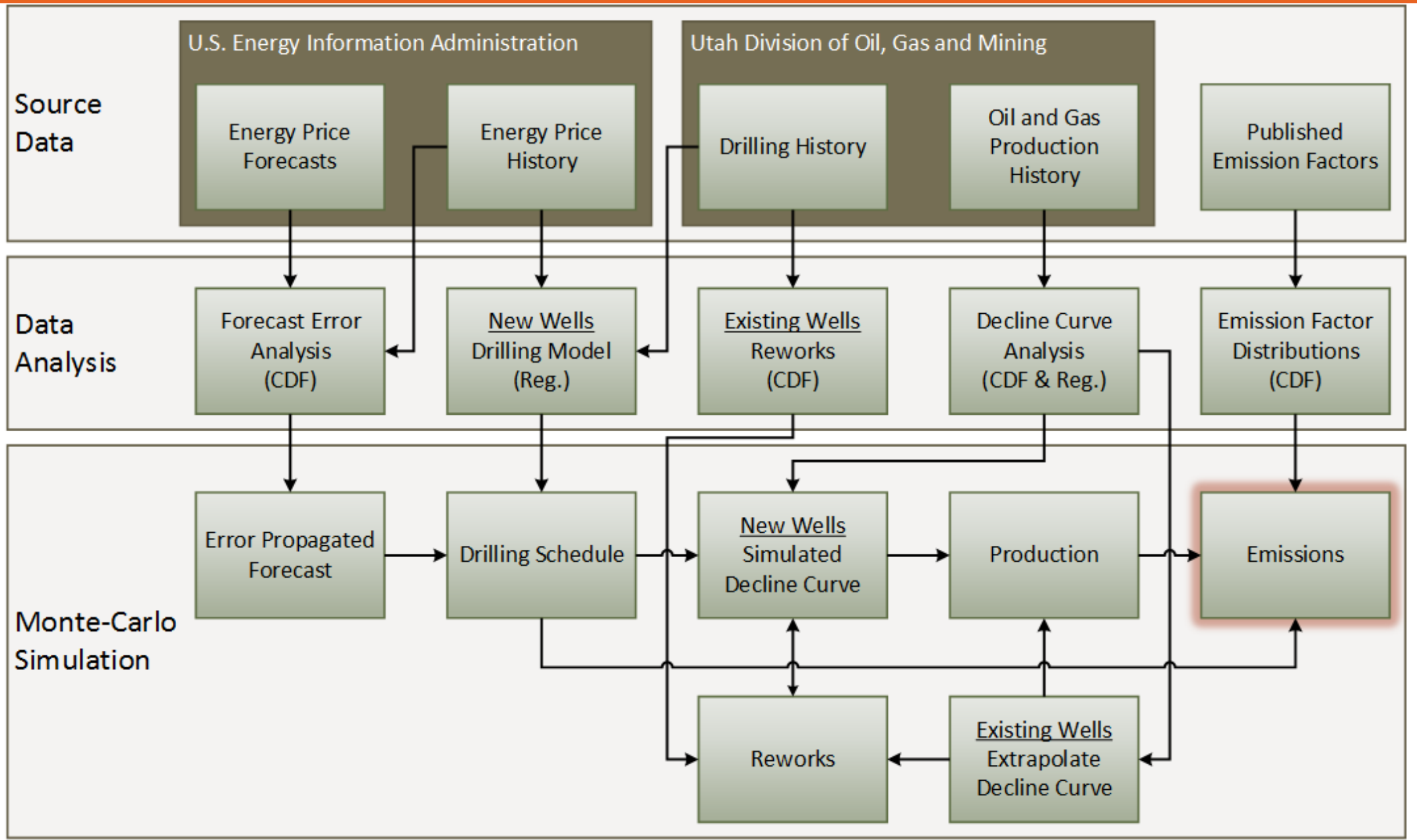
- Background & Objectives
- Methodology & Results
  - Drilling Schedule
  - Production
  - Emissions
- Conclusions

Background

- Oil and gas (O&G) operations have major economic and environmental impacts on the Uinta Basin
  - Pro: employment, taxes, royalties, etc.
  - Con: source of winter-time ozone formation
- Regulators need a method for estimating how much ozone is formed by O&G
- First step to predicting ozone formation rates:
  - What quantity of ozone precursors might be emitted?

Objectives

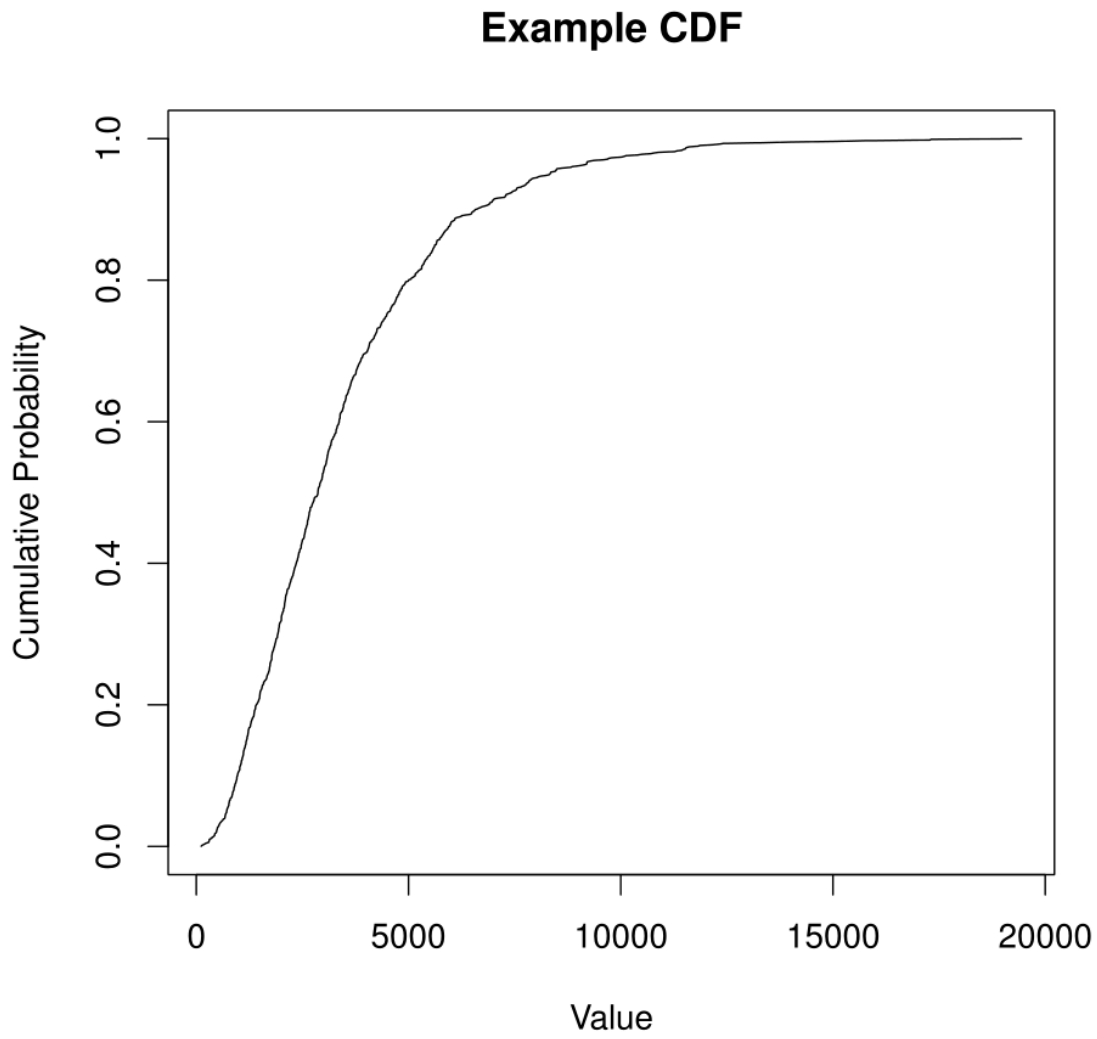
- Predict ozone precursor emissions from O&G by modeling…
  - Drilling schedule as a function of energy prices
  - Production rates with decline curves
  - Emission of ozone precursors with reported emission factors
  - Calculations on a well-by-well basis
  - With uncertainty estimates using Monte-Carlo methods
- Test model's predictive power using cross-validation
- Package method as software tool


Source Data
U.S. Energy Information Administration
Energy Price Forecasts
Energy Price History
Utah Division of Oil, Gas and Mining
Drilling History
Oil and Gas Production History
Published Emission Factors
Data Analysis
Forecast Error Analysis (CDF)
New Wells Drilling Model (Reg.)
Existing Wells Reworks (CDF)
Decline Curve Analysis (CDF & Reg.)
Emission Factor Distributions (CDF)
Monte-Carlo Simulation
Error Propagated Forecast
Drilling Schedule
New Wells Simulated Decline Curve
Production
Emissions
Reworks
Existing Wells Extrapolate Decline Curve

Monte-Carlo Simulation

For each term in model:

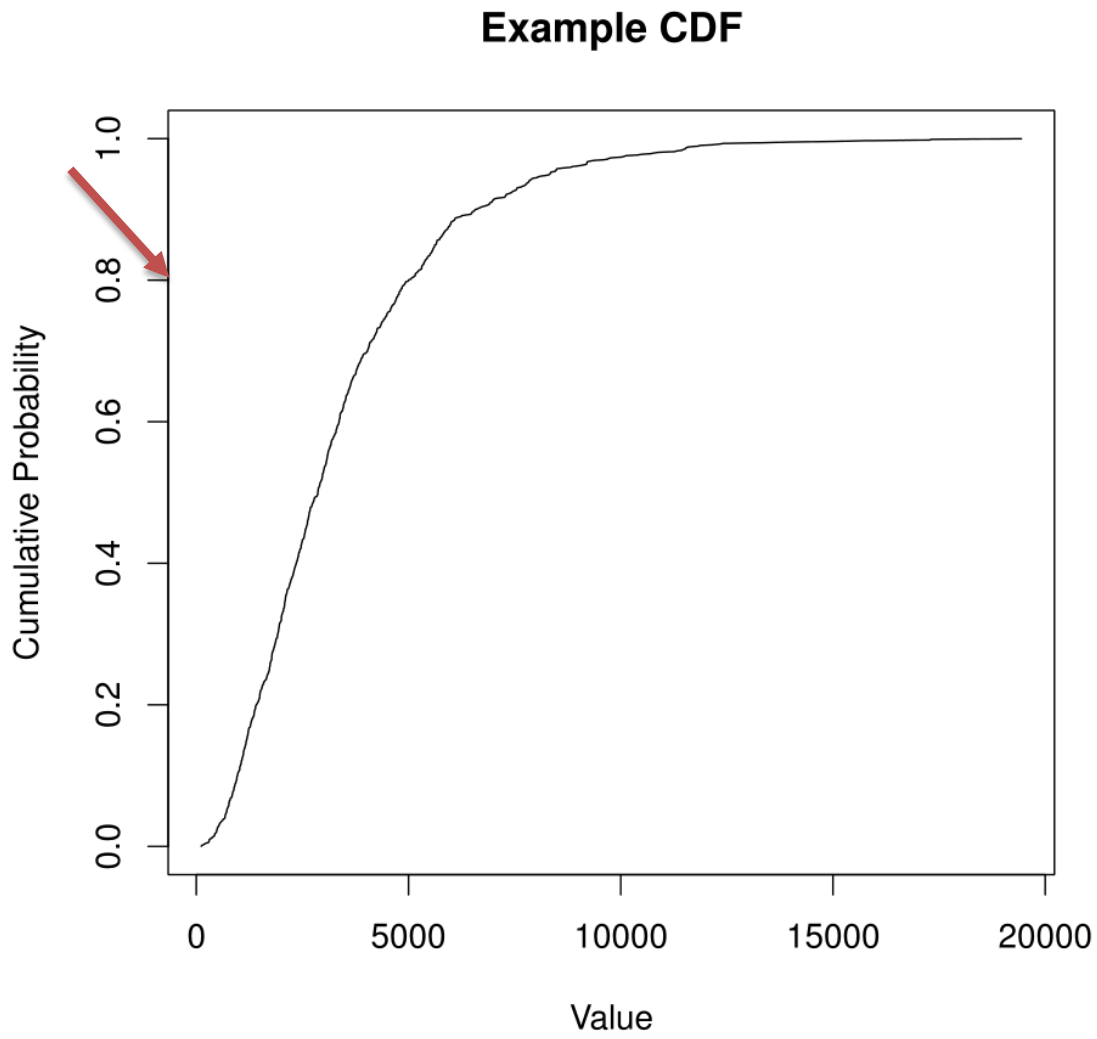
1. Find cumulative distribution function (CDF)



Monte-Carlo Simulation

For each term in model:

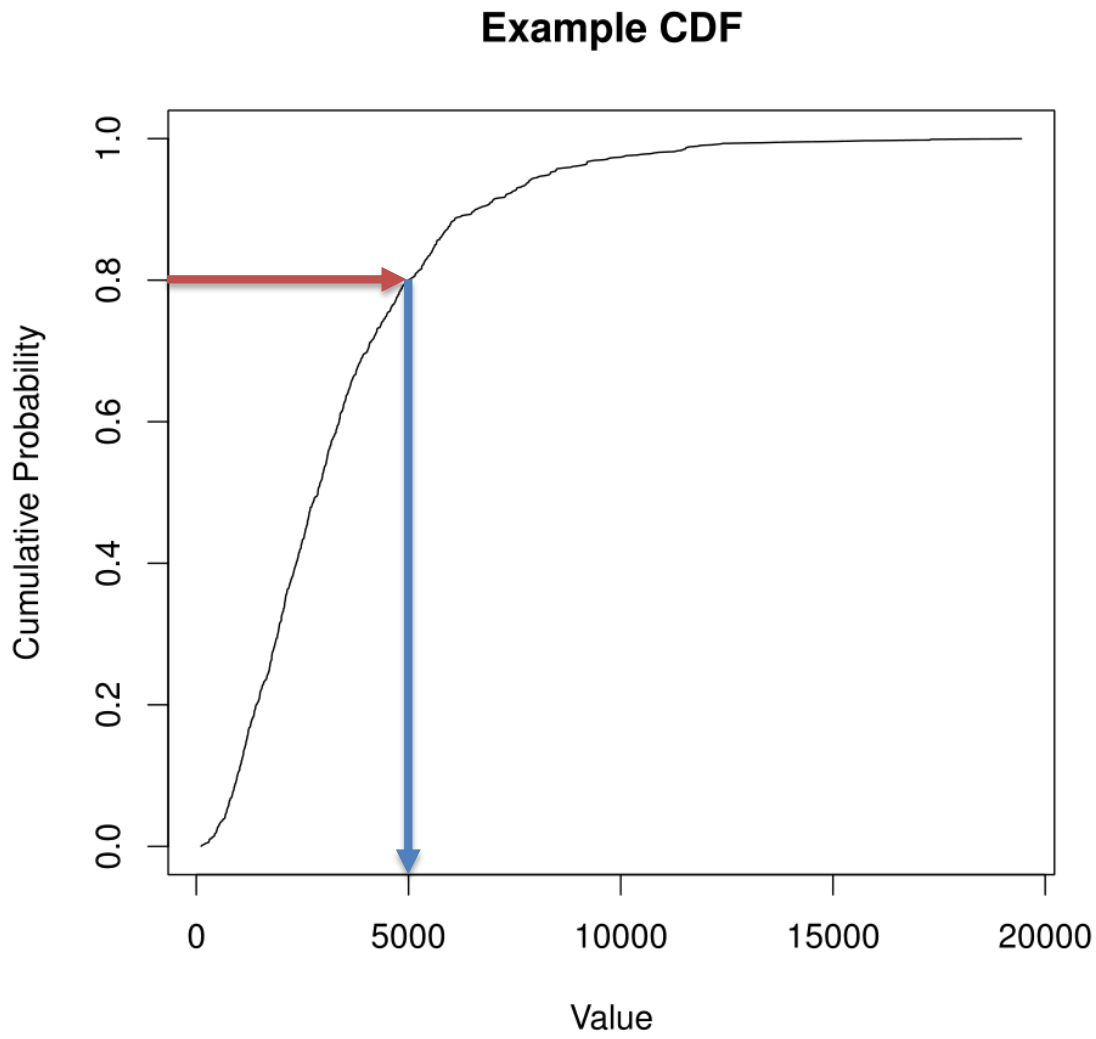
1. Find cumulative distribution function (CDF)
2. Randomly generate number between 0 and 1 (cumulative probability pick)



Monte-Carlo Simulation

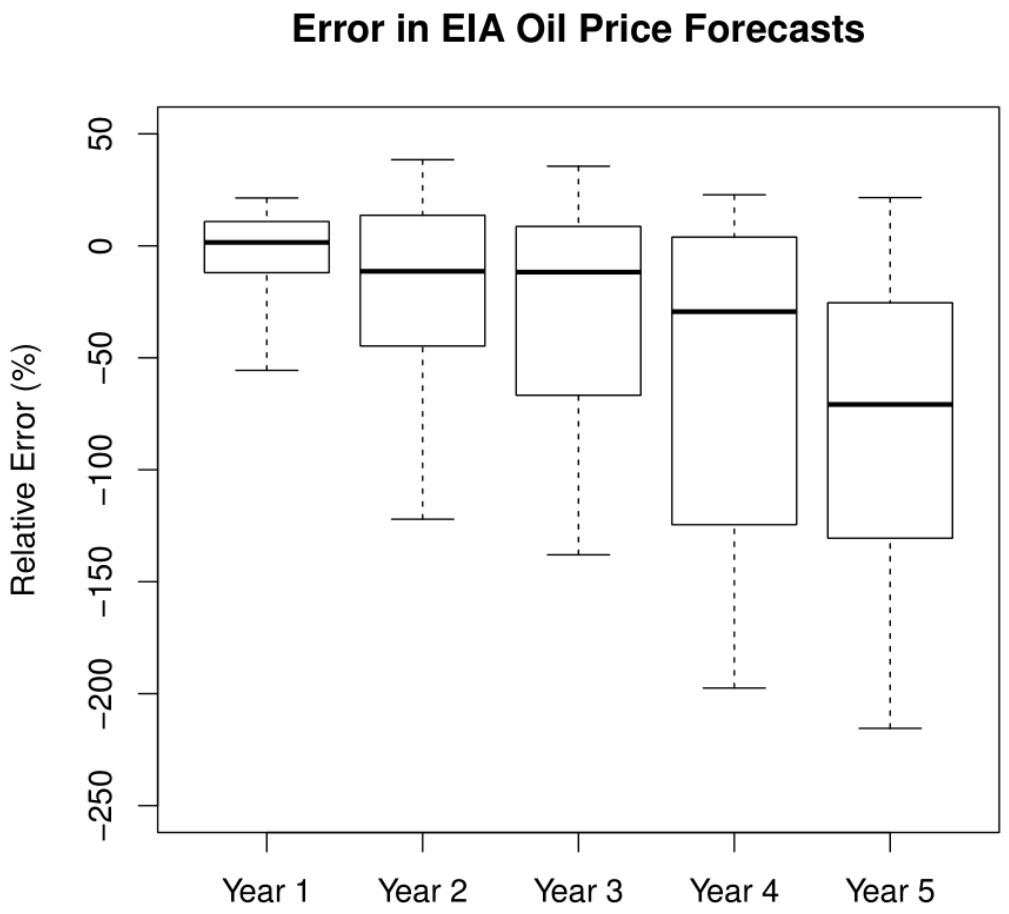
For each term in model:

1. Find cumulative distribution function (CDF)
2. Randomly generate number between 0 and 1 (cumulative probability pick)
3. Find value that matches selected probability pick
4. Repeat many times to get full range of possible outcomes

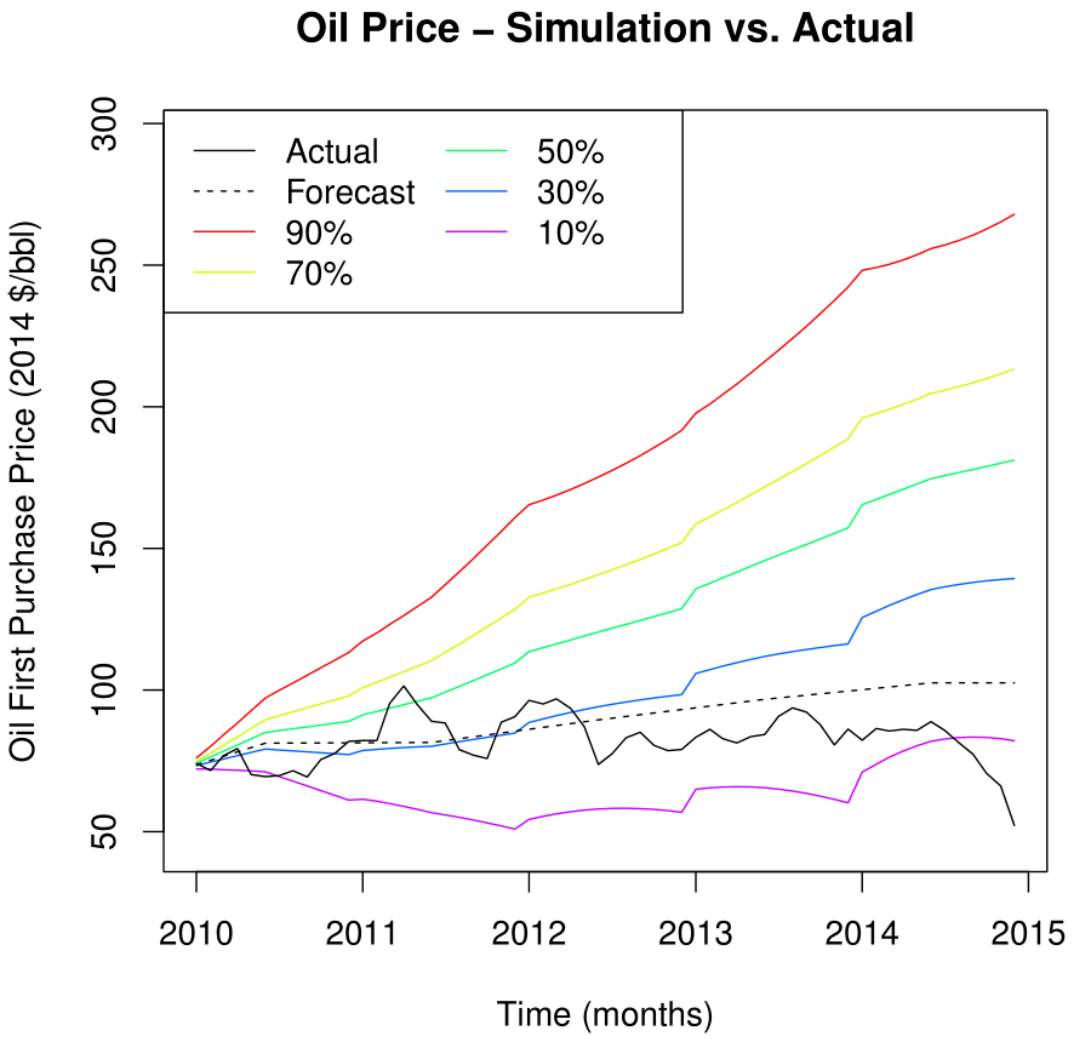


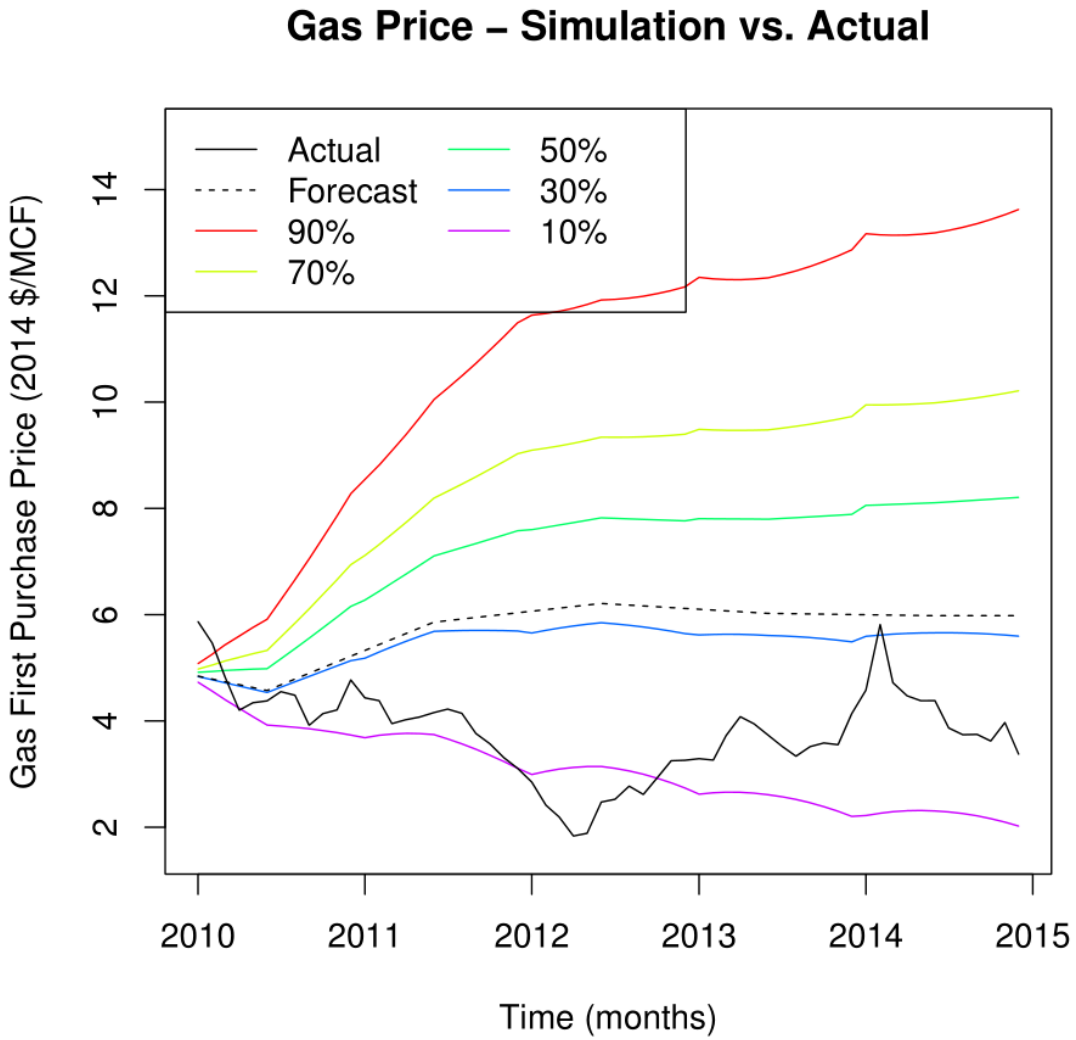
Adding Error to EIA Energy Price Forecast

- EIA forecasts are frequently wrong
- Need price forecasts to include that error/uncertainty
- Accomplished by
  - Find % error between EIA forecast and actual oil/gas prices as f(time)
  - Calculate mean and SD
  - Generate CDF assuming normal distribution



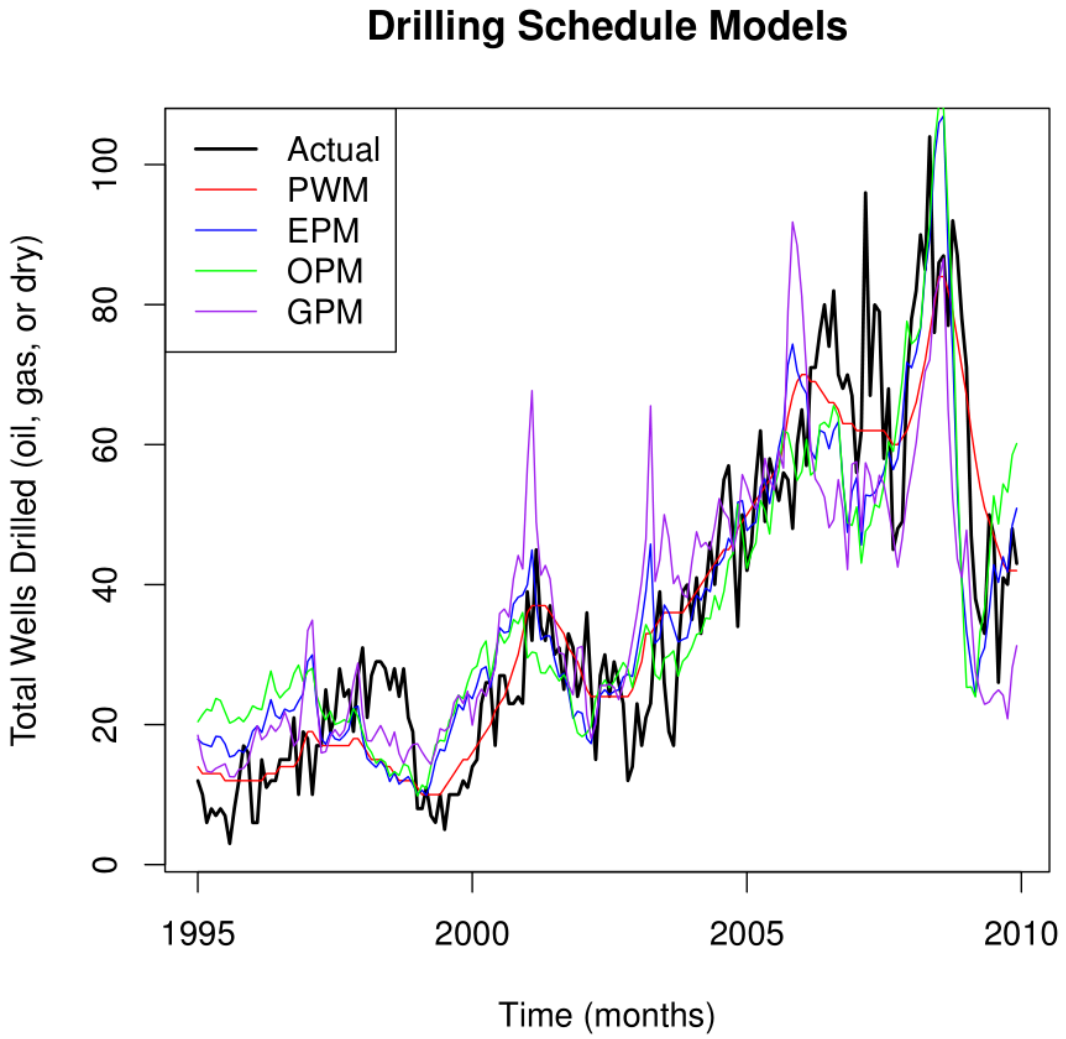
Energy Price Forecast Results





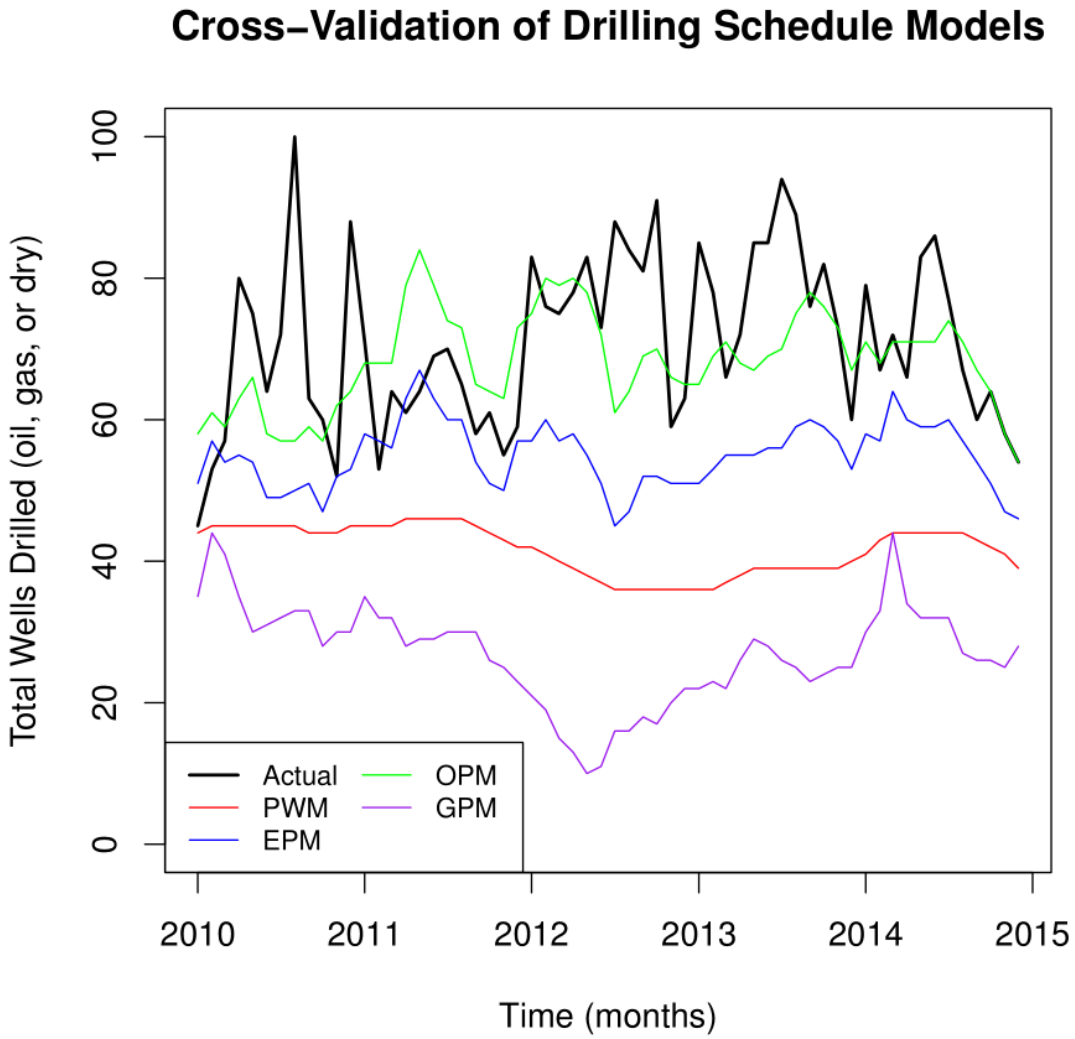
Fitting Drilling Schedule Models

- Tested four models:
  - PWM: $W_t = aOP_t + bGP_t + cW_{t-1} + d$
  - EPM: $W_t = aOP_{t-1} + bGP_{t-1} + c$
  - OPM: $W_t = aOP_{t-1} + b$
  - GPM: $W_t = aGP_{t-1} + b$
- Reasonable fit ($0.61 \leq R^2 \leq 0.86$)



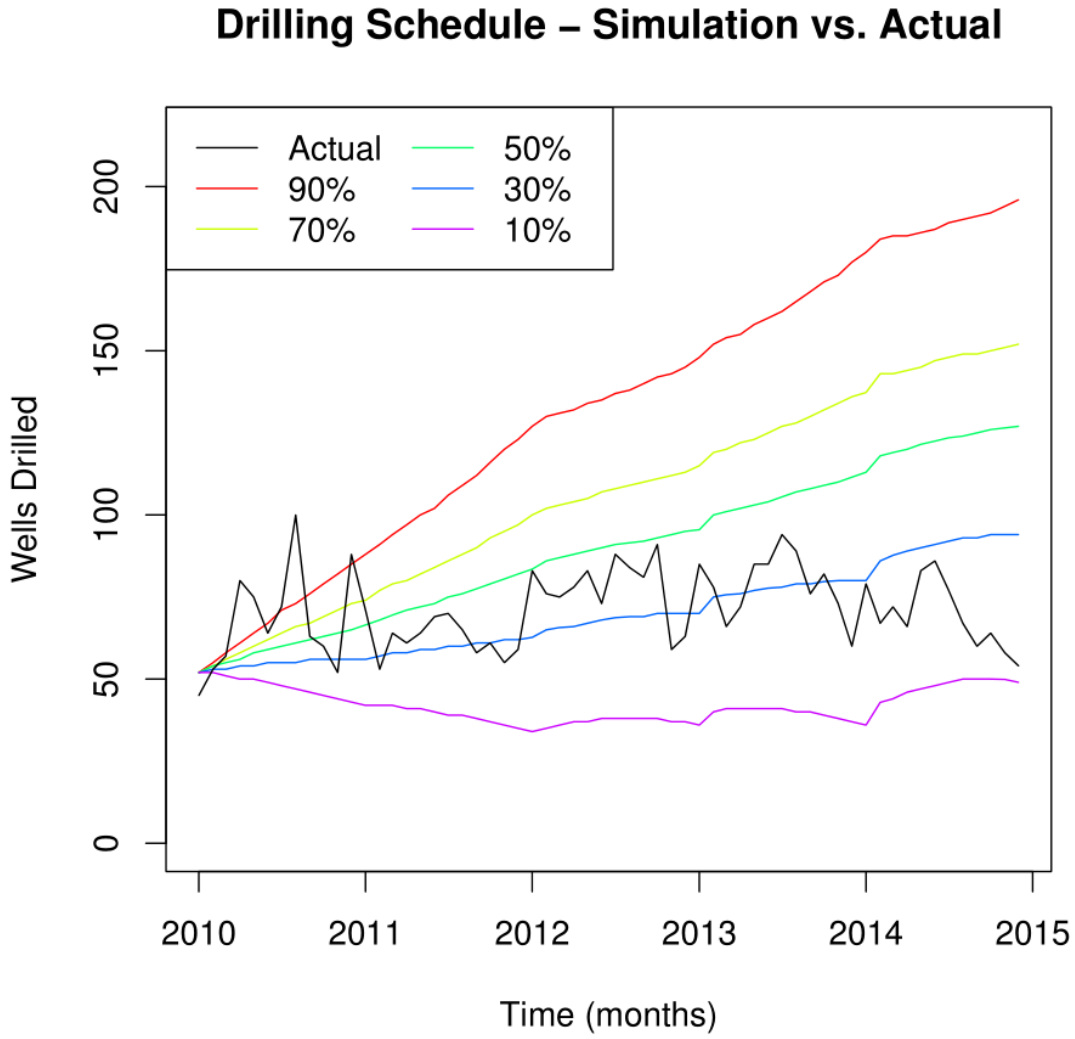
Cross-Validating Drilling Schedule Models

- Tested four models:
  - PWM: $W_t = aOP_t + bGP_t + cW_{t-1} + d$
  - EPM: $W_t = aOP_{t-1} + bGP_{t-1} + c$
  - OPM: $W_t = aOP_{t-1} + b$
  - GPM: $W_t = aGP_{t-1} + b$
- Reasonable fit ($0.61 \leq R^2 \leq 0.86$)
- Range of cross-validation outcomes



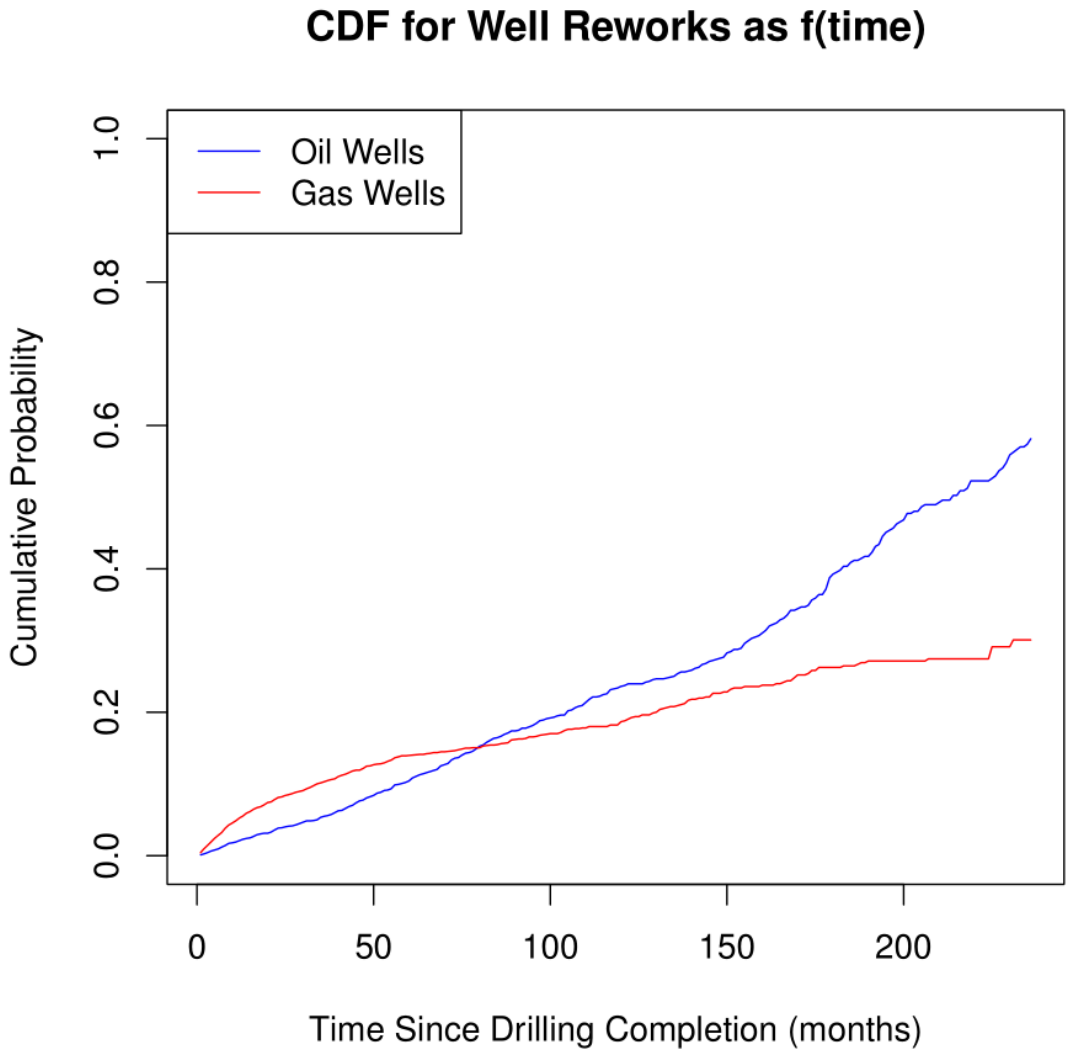
Simulated Drilling Schedule Results

- Tested four models:
  - PWM: $W_t = aOP_t + bGP_t + cW_{t-1} + d$
  - EPM: $W_t = aOP_{t-1} + bGP_{t-1} + c$
  - OPM: $W_t = aOP_{t-1} + b$
  - GPM: $W_t = aGP_{t-1} + b$
- Reasonable fit ($0.61 \leq R^2 \leq 0.86$)
- Range of cross-validation outcomes
- When combined with EPF, covers observed drilling rate ranges



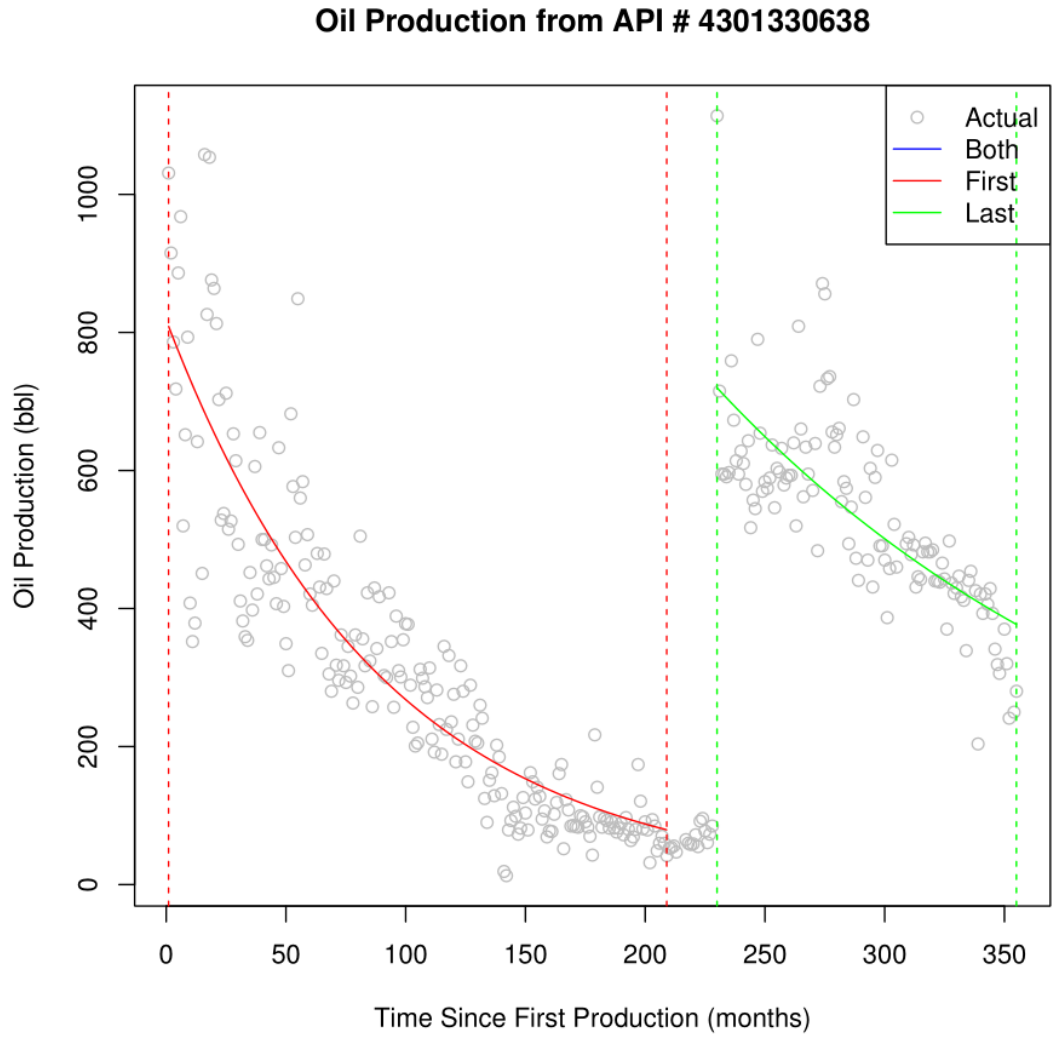
Reworks

- Any well (new or existing) could potentially be reworked
- Currently estimating when reworks occur as f(time)
- Reworked wells are treated as new wells by model
- Reworks that occur before or after modeling period are effectively ignored



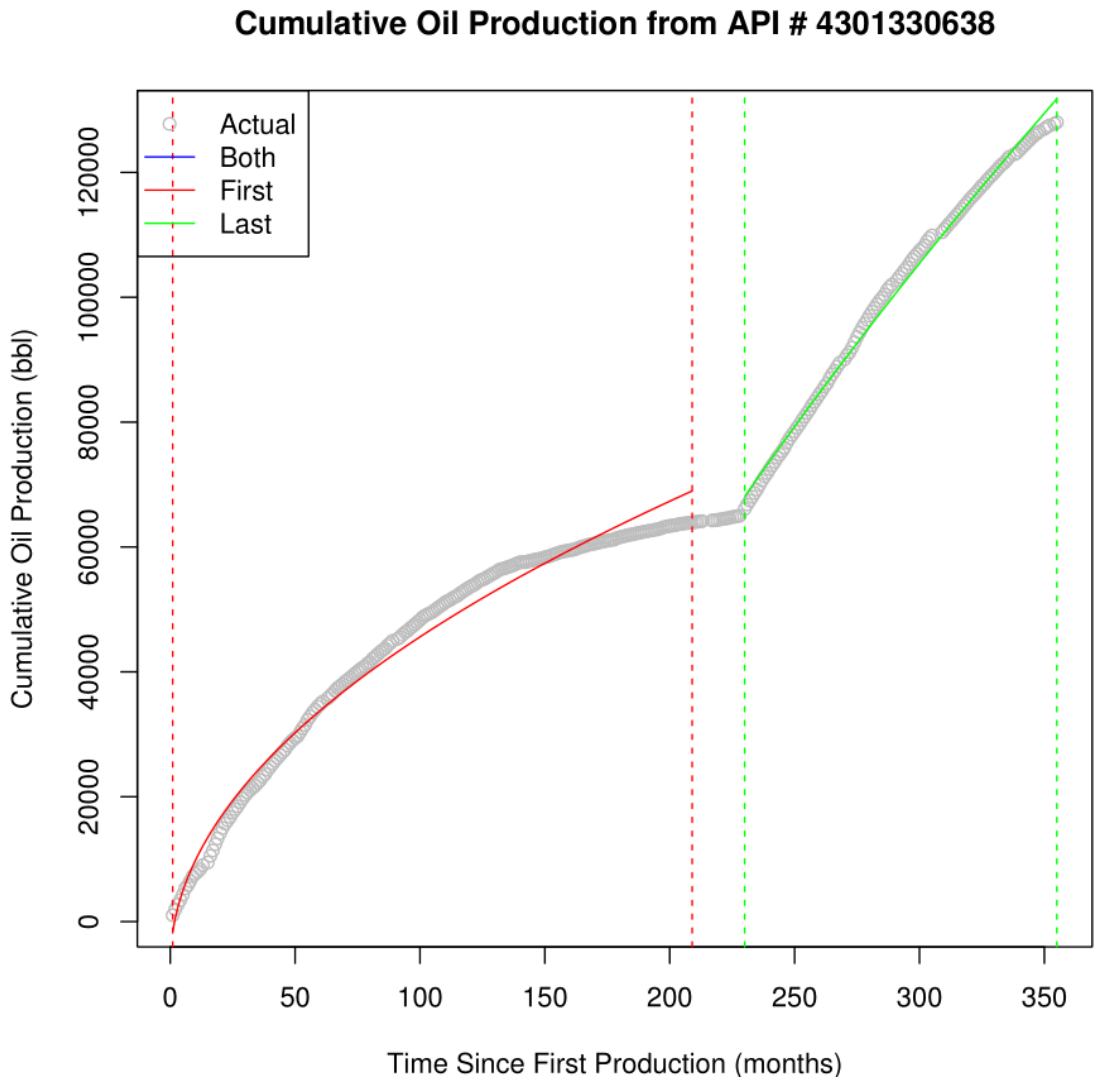
Estimating O&G Production – Decline Curves

- Two approaches
  - Existing wells
    - Hyperbolic decline curve
    - $q(t) = q_o(1 + bD_i t)^{-\frac{1}{b}}$



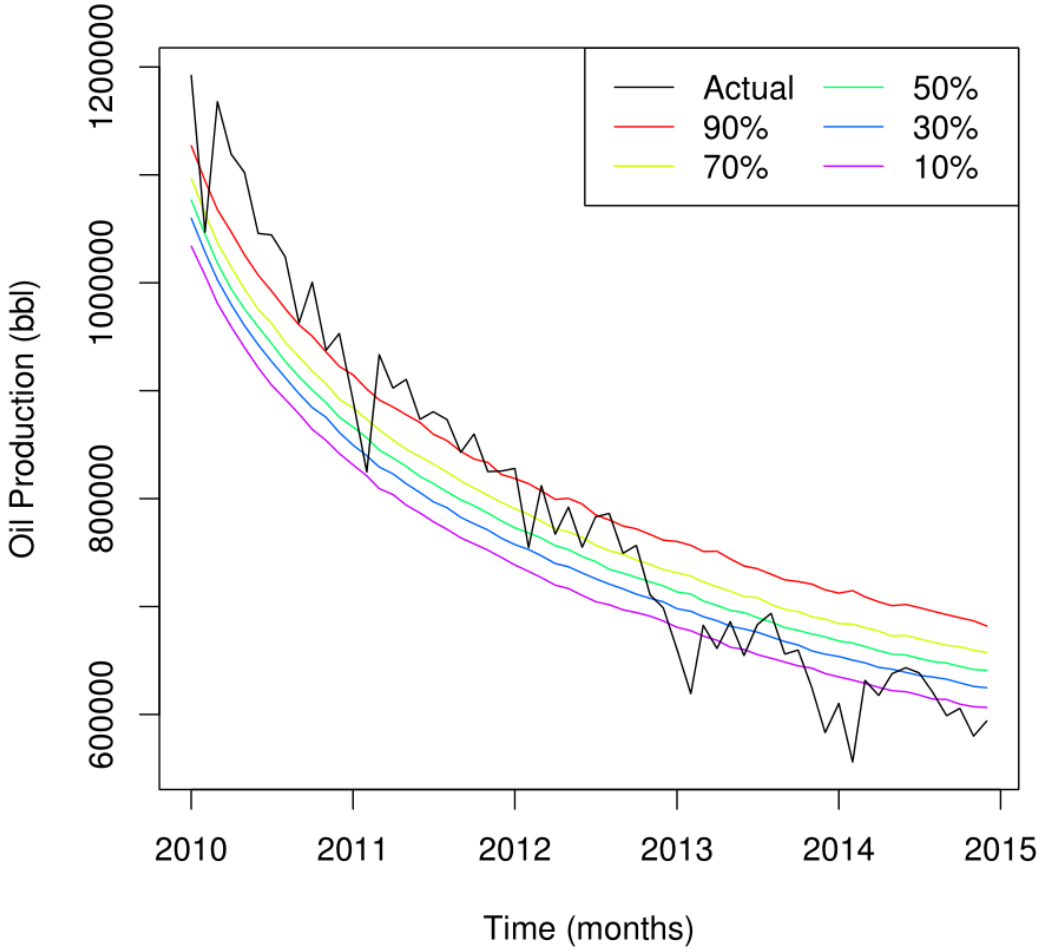
Estimating O&G Production – Decline Curves

- Two approaches
  - Existing wells
    - Hyperbolic decline curve
    - $q(t) = q_o(1 + bD_i t)^{-\frac{1}{b}}$
  - New wells
    - Cumulative production curve
    - $Q(t) = C_p\sqrt{t} + c_1$

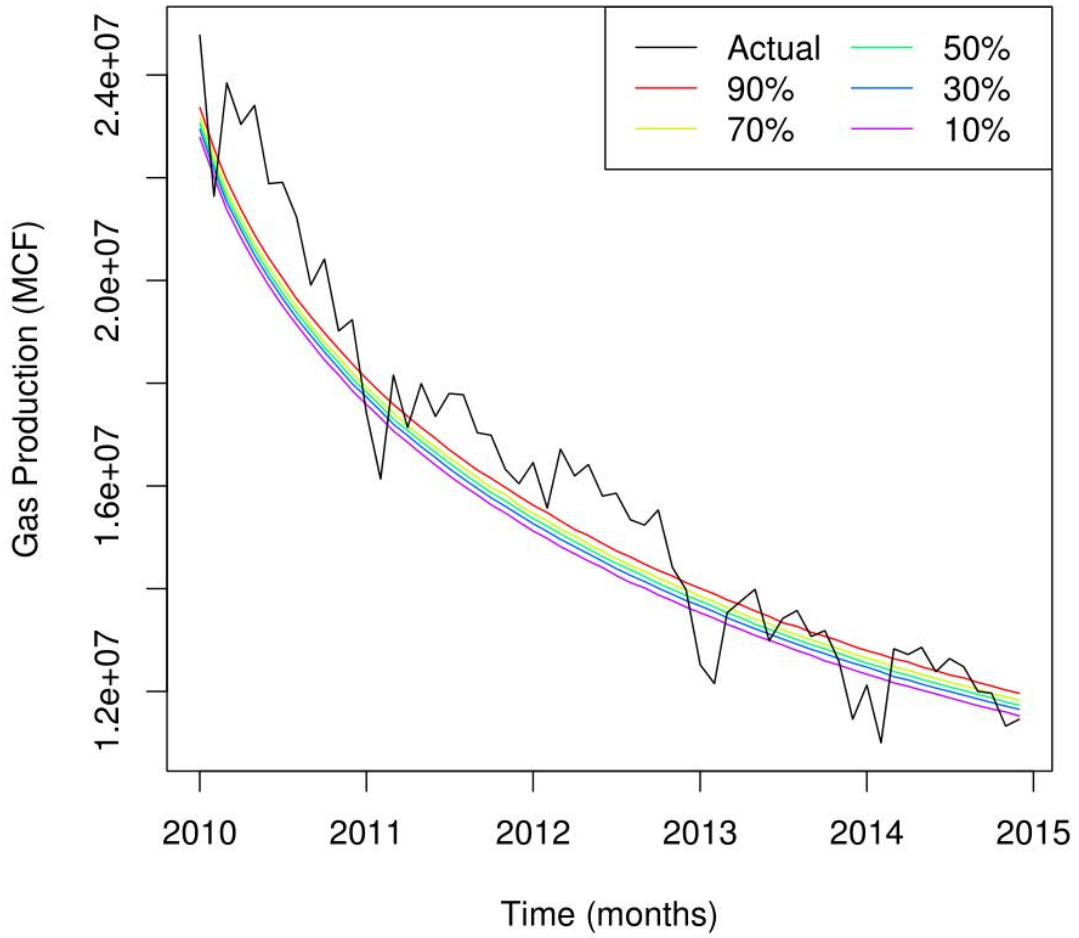


Production Results – Existing Wells

Oil Production from Existing Wells

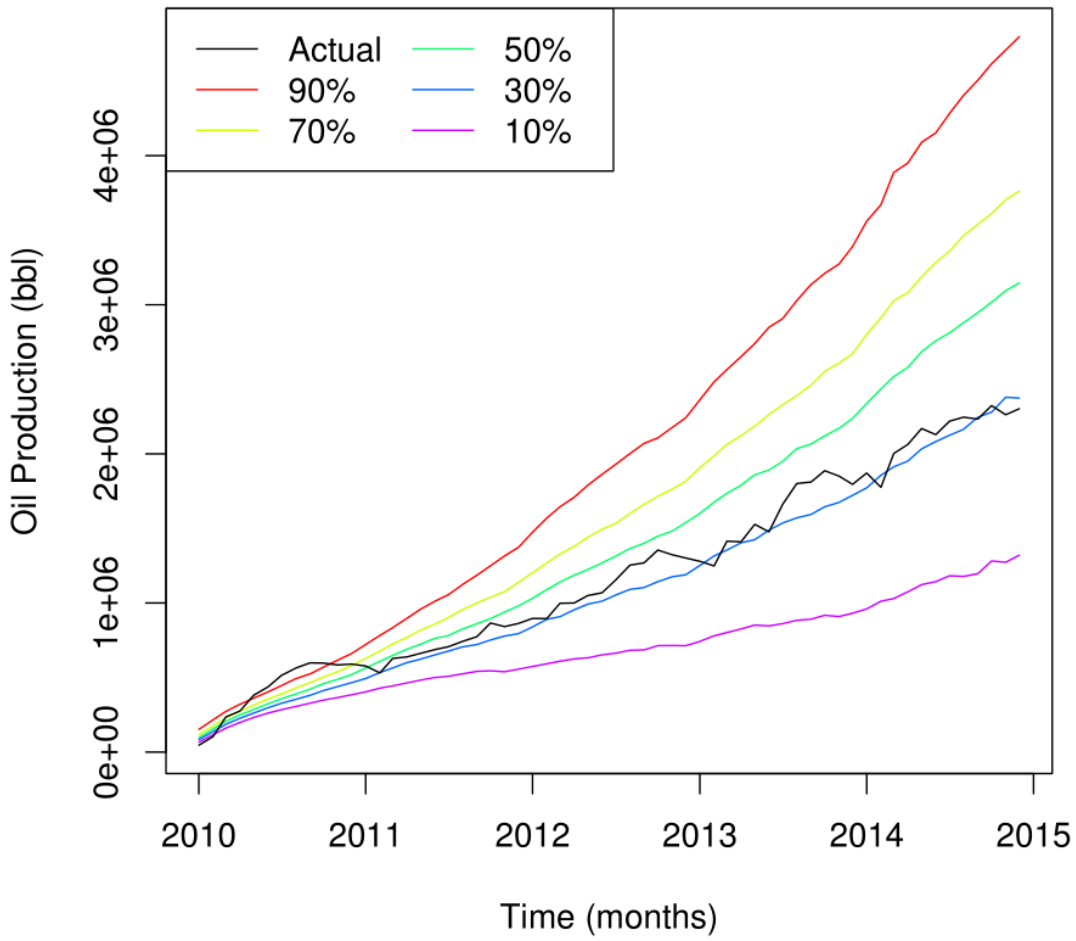


Gas Production from Existing Wells

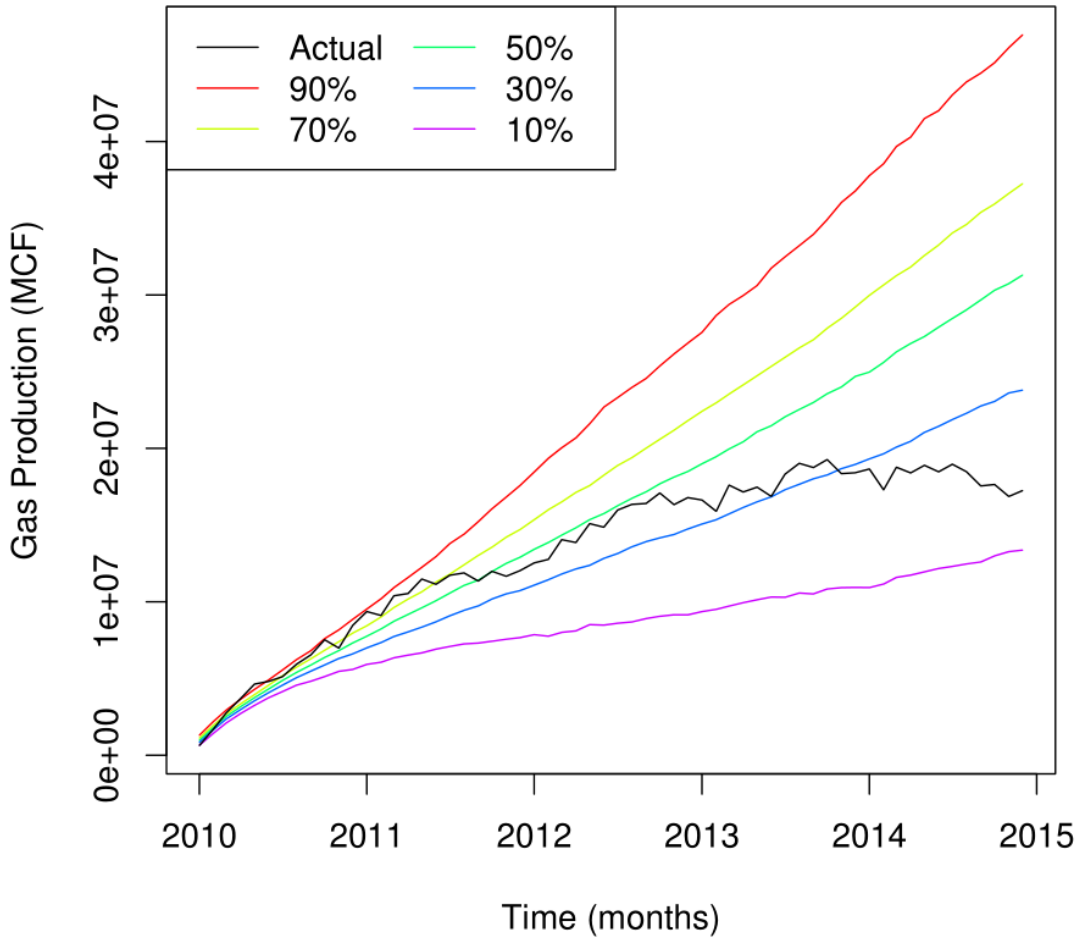


Production Results – New Wells

Oil Production from New Wells

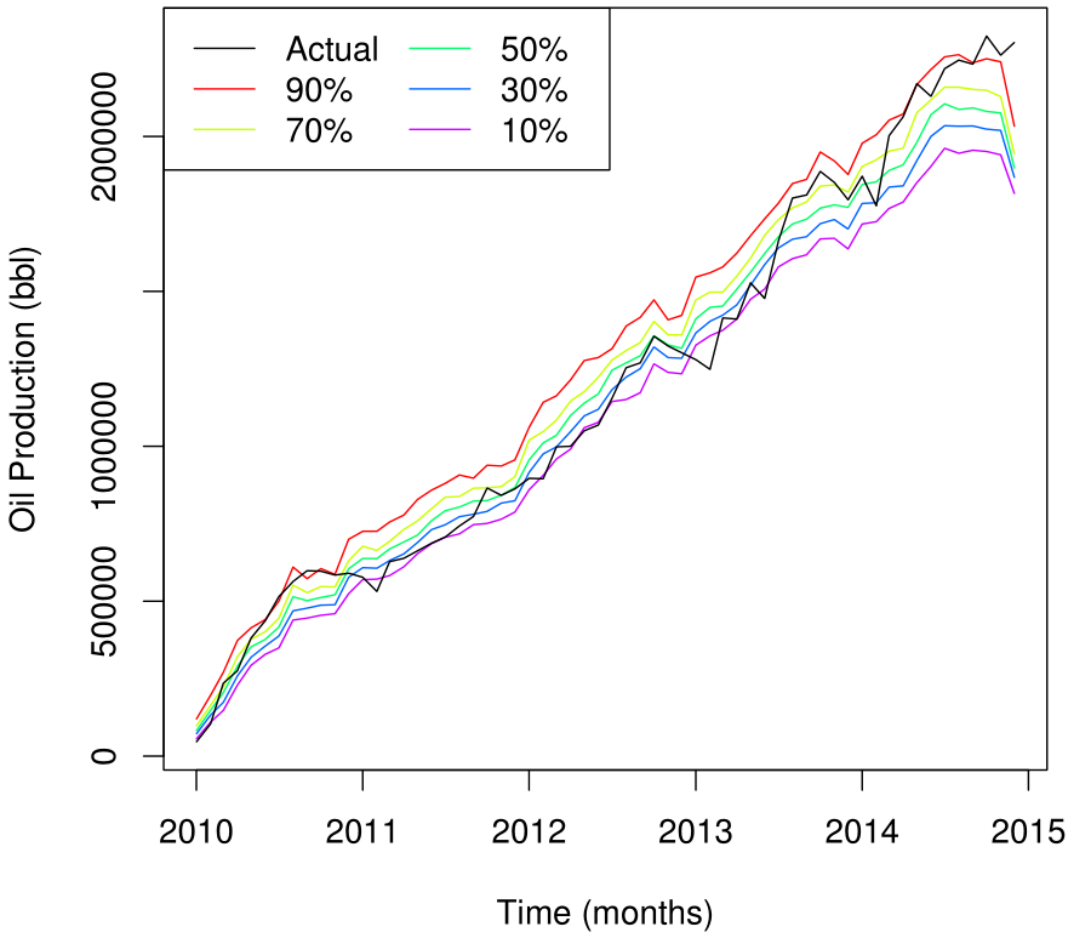


Gas Production from New Wells

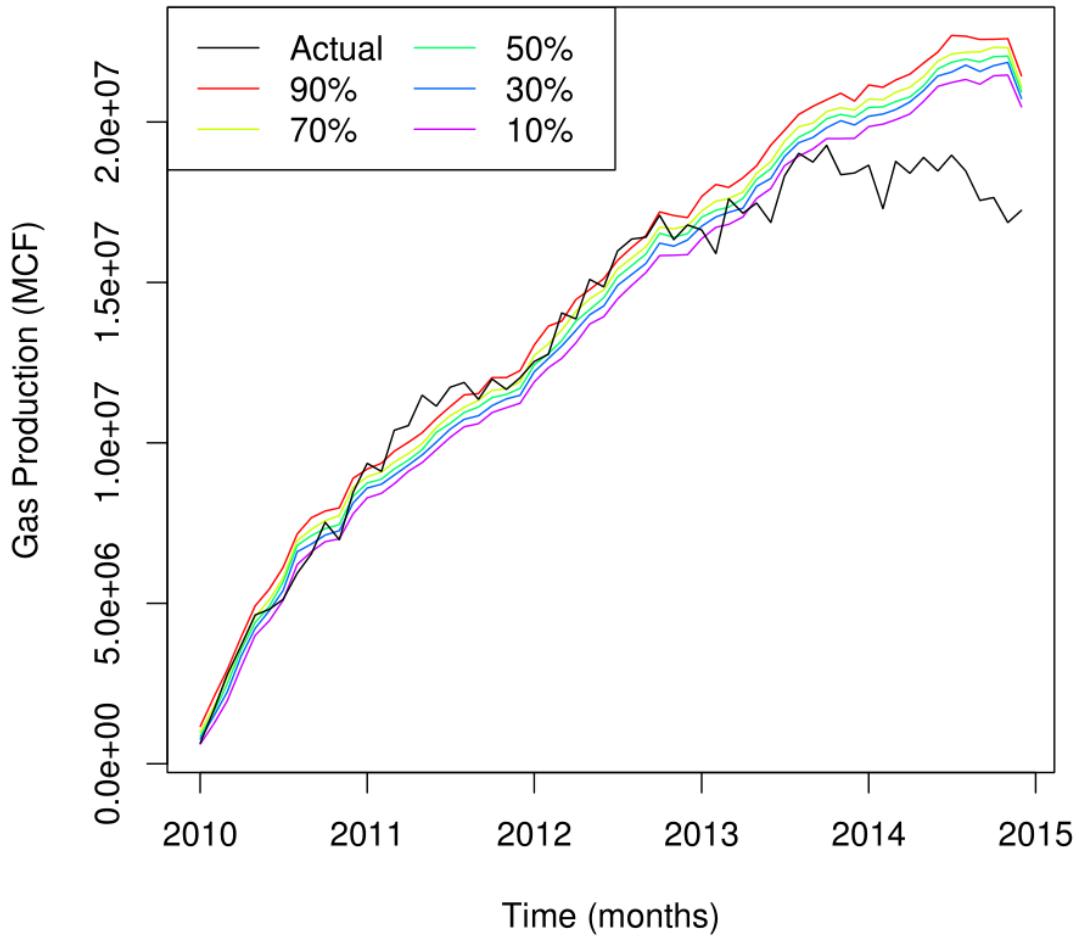


Production with Actual Drilling Schedule

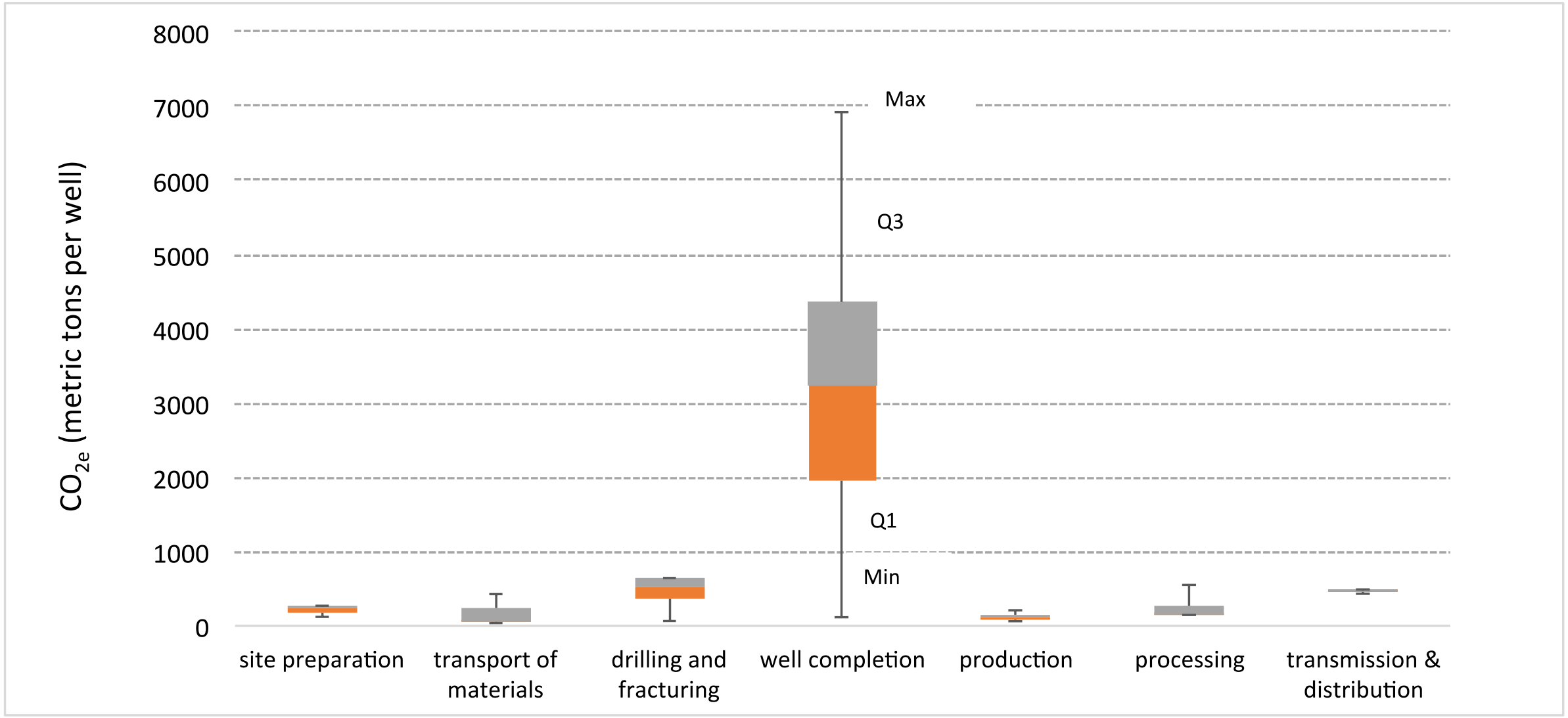
Oil Production from New Wells



Gas Production from New Wells

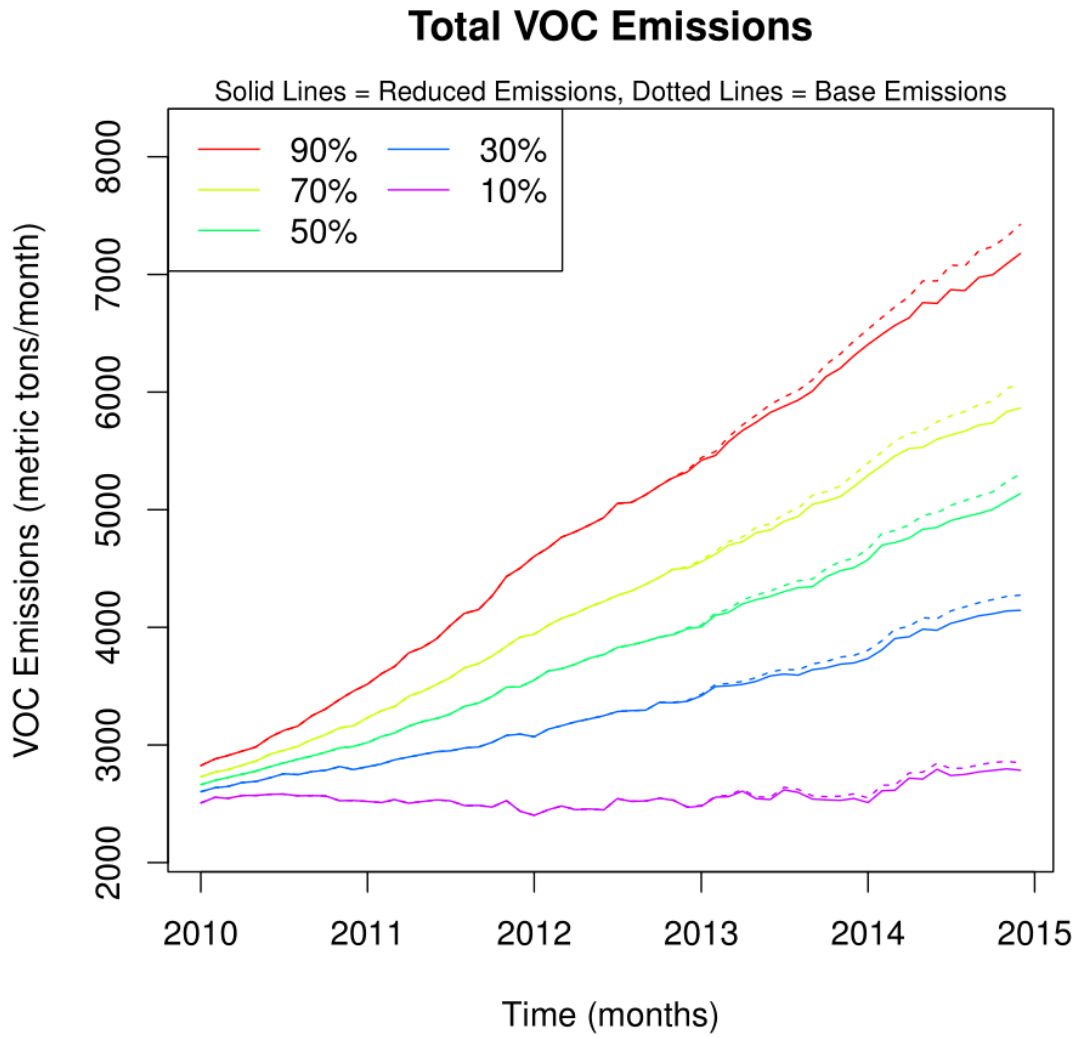


Emissions Factors



Sample Emissions Results

- Calculate emissions from production volumes, drilling schedule, and emission factors
- Can test possible impact of emission reductions by…
  - Emission factor category
  - Well type
  - Location / jurisdiction
  - Time



Conclusions

- Produced software tool that estimates (with uncertainty):
  - Drilling schedule
  - For every well (new and existing):
    - Reworks
    - Oil and gas production
    - Emissions based on user configurable emission factors
- Cross-validated against data from 2010-2014 time period
- Largest source of uncertainty is from economic components of model (energy price forecast and drilling schedule)

Questions?